Chapter VI: Cost-Effectiveness

This section will present the cost-effectiveness analysis we completed for the combined Tier 2 exhaust, Tier 2 evaporative, and gasoline sulfur standards. This analysis relies in part on cost information from Section V and emissions information from Section III to estimate the cost-effectiveness of the standards in terms of dollars per ton of total NOx + NMHC emission reductions. Finally, this Section compares the cost-effectiveness of the new provisions with the cost-effectiveness of other NOx and NMHC control strategies from previous and potential future EPA emission control programs.

A. Overview of the Analysis

The cost-effectiveness analysis conducted for our proposed standards focused on the costs and emission reductions associated with a single vehicle meeting the Tier 2 emission standards, and operating on low sulfur fuel. Both costs and emission reductions were calculated over the life of the vehicle and then discounted at a rate of seven percent. Costs and emission reductions were measured relative to an NLEV baseline and average sulfur levels in the absence of sulfur controls. The calculations were performed separately for each vehicle class and the results weighted according to the expected fleet mix. Details on our approach to cost-effectiveness follow.

1. Temporal and Geographic Applicability

We have taken a per-vehicle approach to our cost-effectiveness calculations that produces $/ton values representing any controlled vehicle, no matter where that vehicle operates. In effect, this means that emission reductions in both attainment and nonattainment areas are included in our cost-effectiveness analysis. We believe that this is appropriate. Both the Tier 2 vehicle and gasoline sulfur programs are proposed to apply nationwide, so that the same emission reductions will occur regardless of where the vehicle operates. Attainment area emission reductions also produce health benefits. In general, the benefits of NMHC reductions in ozone attainment areas include reductions in emissions of air toxics, reductions in the contribution from NMHC emissions to the formation of fine particulate matter, and reductions in damage to agricultural crops, forests, and ecosystems from ozone exposure. Emission reductions in attainment areas help to maintain clean air as the economy grows and new pollution sources come into existence. Also, ozone health benefits can result from reductions in attainment areas, although the most certain health effects from ozone exposure below the NAAQS appear to be both transient and reversible.   The closure letter from the Clean Air Science Advisory Committee (CASAC) for the recent review of the ozone NAAQS states that there is no apparent threshold for biological responses to ozone exposure[1].

In the Regulatory Impact Analysis for a recent rulemaking for highway heavy-duty diesel engine standards[2], EPA also presented a regional ozone control cost-effectiveness analysis in which the total life-cycle cost was divided by the discounted lifetime NOx + NMHC emission reductions adjusted for the fraction of emissions that occur in the regions expected to impact ozone levels in ozone nonattainment areas. (Air quality modeling indicates that these regions include all of the states that border on the Mississippi River, all of the states east of the Mississippi River, Texas, California, and any remaining ozone nonattainment areas west of the Mississippi River not already included.) The results of that analysis show that the regional cost-effectiveness values were 13 percent higher than the nationwide cost-effectiveness values. Because of the small difference between the two results, EPA is presenting only nationwide cost-effectiveness results for this analysis.

Despite the fact that a per-vehicle approach to cost-effectiveness allows us to avoid the arbitrary choice of a specific year in which to conduct the analysis, there is some value in examining different points in time after the program is first implemented. The costs of the program will be higher immediately after it is implemented than they will be after several years, since both vehicle manufacturers and refiners can take advantage of decreasing capital and operating costs over time. For the purposes of this proposed rulemaking, therefore, we will present cost-effectiveness of our proposed program on both a near-term and long-term basis. More details concerning per-vehicle costs are given in Section VI.B.1.

2. Baselines

There are two broad approaches to cost-effectiveness that can be taken, each of which requires a different baseline. These two approaches can be termed "incremental" and "average." Both incremental and average approaches to cost-effectiveness provide a measure of how much more stringent than the existing standards our proposed standards can be before they cease to be cost-effective.

An incremental approach to cost-effectiveness requires that we evaluate a number of different potential standards, each of which is compared to the potential standards closest to it. Using this approach, the cost-effectiveness of our proposed standards would be calculated with respect to another set of potential standards which is less stringent than our proposed standards. In this way, the $/ton values represent the last increment of control, highlighting any nonlinearities that exist in either the costs or emission reductions.

Incremental cost-effectiveness will produce different $/ton values than an average approach to cost-effectiveness only if the costs or emission reductions are nonlinear. In the case of our proposed standards, both the emission reductions and the fuel costs are nearly linear, though the vehicle costs do contain some nonlinearity.

An average approach to cost-effectiveness, on the other hand, requires that we compare the costs and emission reductions associated with our proposed standards to those for the previous set of standards that are being met by manufacturers. In this case, the $/ton values represent the full range of control from the last applicable standard to our proposed standards.

Since today's proposed program includes both fuel standards and vehicle standards, it was necessary for us to define a baseline for both fuels and vehicles. For fuels, there are no previous controls applicable to sulfur (apart from an ASTM limit of 1000 ppm). As a result, we have determined that the sulfur baseline should represent the national average sulfur level that would exist at the time our proposed sulfur standard would go into effect. The national average sulfur content of current conventional gasoline is approximately 330 ppm. We are not projecting the sulfur level of conventional gasoline to change over the next ten years in the absence of specific sulfur controls. For Phase II reformulated gasoline (RFG), the average sulfur content is projected to be 150 ppm in the summer and 300 ppm in the winter[a]. Based on seasonal volume data, we estimate that 40 vol% of the annual pool is summer gasoline, with the remainder being winter gasoline, producing an annual Phase II RFG sulfur level of 240 ppm. Because estimating the number of areas that will continue to be in the RFG program by the middle of the next decade is highly speculative, we have assumed that the current volume split between RFG and conventional gasoline will continue indefinitely. Thus we estimated that Phase II RFG will account for 26.7 percent of the total gasoline pool. As a result, we calculated the national average sulfur level for the next decade to be 305 ppm. This is the baseline sulfur level used in our calculations.

For the exhaust emission standards applicable to light-duty vehicles and trucks, there are two potentially valid baselines that could be used. The Clean Air Act (CAA) suggests that Tier 2 vehicle standards should be compared to the previous set of federal light-duty standards, termed Tier 1 standards. However, the language does not explicitly require that the cost-effectiveness determination use Tier 1 standards as the baseline. Since the passage of the CAA Amendments of 1990, the National Low Emission Vehicle (NLEV) program has gone into effect. NLEV includes light-duty standards that are more stringent that Tier 1 for LDV, LDT1, and LDT2. NLEV did not exist in 1990 and was not envisioned by the authors of the CAA Amendments of 1990. Had NLEV existed, either in concept or as a formal program, we believe that it could have been identified in the CAA as the point of comparison for evaluating Tier 2 standards. In addition, NLEV standards represent the most recent set of standards with which manufacturers must comply. For our proposal, therefore, we have decided to make NLEV the baseline on which the vehicle side of our cost-effectiveness calculations are based. Further, these NLEV vehicles would be SFTP compliant since they would be sold in 2004 (the first year of our proposed Tier 2 program).

The NLEV program did not include new standards for evaporative emissions, and so cannot be used as the baseline for evaluating the cost-effectiveness of our proposed Tier 2 evaporative emission standards. Instead, the 2.0 gram/test standards under the enhanced evaporative procedure, initially implemented in 1996, have been used as the baseline.

[a] Based on a consensus opinion of the multi-party Phase II RFG Implementation Team, and summarized in a report entitled, "Phase II RFG Report on Performance Testing." Contact: Deborah Wood, Office of Mobile Sources.

B. Costs

The costs used in our cost-effectiveness calculations are the sum of the costs of compliance with the Tier 2 exhaust, Tier 2 evaporative, and gasoline sulfur standards on a per-vehicle basis. Costs are given in 1997 dollars, and result from discounting over the lifetime of a vehicle at a seven percent discount rate. In addition, all costs represent the fleet-weighted average of light-duty vehicles and trucks.

1. Near and Long-Term Cost Accounting

Since the costs of complying with both the Tier 2 exhaust and gasoline sulfur standards will vary over time, we determined that it is appropriate to consider both near-term and long-term costs in our cost-effectiveness analysis. First, the capital costs associated with the manufacture of vehicles that meet the proposed Tier 2 standards are generally amortized over five years. Thus in the sixth year of production, a portion of the capital costs become zero and the total costs of production drop. Manufacturers also gain knowledge about the best way to meet new standards as time goes on, and as a result their operating costs decrease over time. As described in a recent rulemaking setting standards for non-road compression ignition engines, we have determined that the cost-implications of this "learning curve" can be estimated as a 20 percent drop in operating costs in the third year of production.

Thus near-term costs represent the highest costs of the program, as they include all capital costs and no cost savings due to the manufacturer's learning curve. Long-term costs, on the other hand, represent the lowest costs of the program which occur after a portion of capital cost amortizations have ended and all learning curve cost savings have been accounted for. For the purposes of this proposed rulemaking, therefore, we will present cost-effectiveness of our proposed program on both a near-term and long-term basis.

Because of our per-vehicle approach to cost-effectiveness, near-term and long-term costs are not associated with any specific year of our proposed Tier 2 program. For instance, the costs associated with our proposed gasoline sulfur control program will decline steadily due to rotating capital expenditures and continuous improvements in catalyst design. Vehicle costs, however, decline over a different schedule. Not only are the vehicle-related capital costs amortized over five years instead of the longer, rotating schedule for gasoline sulfur, but the phase-in schedule for the Tier 2 exhaust standards varies depending on vehicle class. Therefore, the near-term costs actually represent a conservative view of the costs of our proposed program, since they consider the highest vehicle and fuel costs as if they occurred at the same time for all vehicle classes. The long-term costs, on the other hand, represent the case for some later year of the Tier 2/gasoline sulfur program in which a majority of the fleet is meeting our proposed standards. In this case, the phase-in schedule for light-duty vehicles and trucks is no longer evident in the fleet mix, a portion of capital cost amortizations have ended, and most learning curve cost savings will have been taken into account. Details about the calculation of near and long-term vehicle and fuel costs can be found in Sections V.A.1 and V.B.2.

2. Vehicle and Fuel Costs

The per-vehicle costs used in our cost-effectiveness calculations were derived and presented in the preceding sections. Vehicle costs were presented in Table V-12 for the five vehicle categories affected by our proposed standards. For the purposes of calculating cost-effectiveness, we first subtracted out the costs attributable to compliance with our proposed evaporative emission standards, then weighted the remaining costs for those five individual vehicle categories by the expected fleet fractions to obtain fleet-average costs for our proposed exhaust emissions standards. Also, we treated first-year production costs as the "near-term" costs, and sixth-year production costs as the "long-term" costs. Costs associated with compliance with our proposed evaporative emission standards were constant across all vehicle classes at $4.10 per vehicle. For low sulfur gasoline, we used the discounted lifetime costs presented in Table V-41. The costs used in our cost-effectiveness calculations are repeated in Table VI-1.

Table VI-1. Fleet-average, Per-vehicle Costs Used in Cost-effectiveness

	Vehicle-exhaust ($)	*Vehicle-evap ($)*	*Fuel ($)*	*Total costs ($)*
Near-term	124.04	4.10	101.92	230.06
Long-term	89.47	4.10	94.86	188.43

Note that the total costs in Table VI-1 were used for establishing "uncredited" cost-effectiveness values. As described in the next section, the costs from Table VI-1 were also adjusted to produce "credited" cost-effectiveness values.

3. Cost Crediting for PM and SO_2

The object of our cost-effectiveness analysis is to compare the costs to the emission reductions in an effort to assess the program's efficiency in helping to attain and maintain the NAAQS. Thus we recognize that the primary purpose of our proposed standards is to reduce emissions of hydrocarbon and oxides of nitrogen emissions from the affected vehicles. That is why we determined that cost-effectiveness should be calculated on the basis of total NOx + NMHC emissions. However, we also believe that reductions in other pollutants which produce health or welfare benefits should be included in the cost-effectiveness assessment, since they also represent a value of our proposed program.

The reduction in gasoline sulfur levels that would result from our proposed standards will necessarily result in reductions in sulfur-containing compounds that exit the tailpipe. These compounds are limited to sulfur dioxide (SO_2) and sulfate particulate matter. To account for reductions in emissions of these two pollutants in our cost-effectiveness calculations, we have calculated a second set of $/ton values in which we credit some of the costs to SO_2 and direct sulfate PM, with the remaining costs being used to calculate $/ton NOx+NMHC. As a result, we have produced both "credited" and "uncredited" $/ton NOx+NMHC values; the former takes into account the SO_2 and direct PM emission reductions associated with our proposed standards, while the latter does not.

Cost-effectiveness values for the control of SO_2 and direct PM represent conservative estimates of the cost of measures that will need to be implemented in the future in order for all areas to reach attainment. Such cost-effectiveness values are therefore an appropriate source for estimating the amount of the costs to credit to these pollutants. As a result, we credited some costs to SO_2 and direct PM through the application of cost-effectiveness ($/ton) values for these two pollutants withdrawn from other sources.

In concept, we would consider the most expensive program needed to reach attainment a good representation of the ultimate value of PM or SO_2. However, in this rulemaking, we chose to simplify by using more conservative approaches to establish crediting values for PM and SO_2. The potential future programs evaluated as part of the NAAQS revisions rulemaking (discussed in more detail in Section VI.D below) provided a reasonable source for identifying the value of SO_2 and direct PM in terms of their cost-effectiveness.

Out of the nine SO_2 control programs evaluated in the NAAQS revisions rule, eight were actually used in the modeling of ambient concentrations of PM based on their contribution to secondary PM (sulfate) levels in PM nonattainment areas. The modeling showed that these eight programs, along with other PM control programs as described above, permitted 70 percent of counties not meeting the annual 8-hour PM standard to come into attainment. The cost-effectiveness of the eight SO_2 control programs ranged from $1600/ton to $111,500/ton. In this particular rulemaking, rather than attempt to identify a more precise credit value for SO_2 based on the last measures needed for attainment, we have for simplicity's sake used the average cost effectiveness of the eight SO_2 control programs, calculated to be $4800 a ton. This average value of $4800/ton was used in the crediting of some costs to SO_2, and represents a conservative valuation of SO_2.

The NAAQS revisions rule also evaluated PM control strategies, accounting for both PM_{10} and $PM_{2.5}$. The average cost-effectiveness for the PM control strategies considered in the NAAQS revisions rule ranged from $2,400/ton (for PM_{10}) to $12,900/ton (for $PM_{2.5}$). However, a recent rulemaking setting standards for urban busses[3] determined that the cost-effectiveness of PM control for these heavy-duty diesel engines was $10,000 - $16,000/ton. In this particular rulemaking, rather than attempt to identify an more precise credit value for PM based on the last measures needed for attainment, we have for simplicity's sake used $10,000/ton as a conservative but reasonable crediting value for PM for our proposed standards.

The cost crediting was applied after all costs associated with compliance with our proposed standards were calculated and summed. The per-vehicle tons reduced of both direct PM and SO_2 were multiplied by the respective cost-effectiveness values of $10,000/ton and $4800/ton (see Sections VI.C.3 and VI.C.4 below for tons calculations). As a result, $53.73 of the total costs were apportioned to SO_2, while $3.96 was apportioned to direct PM. These amounts are independent of whether we are considering a near-term or long-term cost-effectiveness calculation, since the total tons reduced for these two compounds is the same, on a per-vehicle basis, in any year of the program. A summary of the costs used in our cost-effectiveness calculations is given below in Table VI-2.

Table VI-2. Fleet Average Per-vehicle Costs Used in Cost-effectiveness

	Near-term costs ($)	*Long-term costs ($)*
Total uncredited costs	230.06	188.43
SO_2 credit allocation	-53.73	-53.73
Direct PM credit allocation	-3.96	-3.96
Total credited costs	172.37	130.74

C. Emission Reductions

In order to determine the overall cost-effectiveness of the standards we are proposing, it was necessary to calculate the lifetime tons of each pollutant reduced on a per vehicle basis. This section will describe the steps involved in these calculations. In general, emission reductions were calculated for NOx, NMHC, primary PM, and SO_2 in a manner analogous to the discounted lifetime fuel costs described in Section V.B.4.

1. NOx and NMHC

Our proposed standards are intended primarily to reduce emissions of NOx and NMHC. We have determined that the cost-effectiveness of our proposed standards should be determined for both NOx and NMHC. Several past rulemakings which produced reductions in both of these pollutants have taken an approach to cost-effectiveness that sums the NOx and NMHC emission reductions. This approach leads to $/ton NOx+NMHC. In addition, many standards for mobile sources have been established in terms of NOx+NMHC caps. Thus we believe that this approach to cost-effectiveness is appropriate for our proposed Tier 2 standards as well, because we are proposing more stringent exhaust standards for both NOx and NMHC (separately). This approach also allows for a direct comparison to previous programs for which NOx and NMHC were summed in the cost-effectiveness analyses.

The discounted lifetime tonnage numbers for NOx, exhaust NMHC, and evaporative NMHC were based on average in-use emission levels developed for EPA's proposed MOBILE6 on-highway inventory model. These in-use emission levels were expressed in terms of average gram/mile emissions for each year in a vehicle's life, up to 25 years. From this basis, lifetime tonnage estimates were developed using the following procedure:

1) Annual mileage accumulation levels proposed for MOBILE6 were applied to the in-use emission rates for each year in a vehicle's life to generate total mass emissions produced in each year by that vehicle.

2) The resultant mass emissions were multiplied by the probability of survival in the appropriate year, known as the "survival" rate, from estimates for cars and trucks published by NHTSA[4].

3) A seven percent annual discount factor, compounded from the first year of the vehicle's life, was then applied for each year to allow calculation of net present value lifetime emissions.

Converting to tons and summing across each year results in the total discounted lifetime per-vehicle tons. This calculation can be described mathematically as follows:

$$LE = \sum [\{(AVMT)_i \bullet (SURVIVE)_i \bullet (ER)_i \bullet (K)\}/(1.07)^{i-1}]$$

Where:

LE	= Discounted lifetime emissions in tons/vehicle
$(AVMT)_i$	= Annual vehicle miles traveled in year i of a vehicle's operational life
$(SURVIVE)_i$	= Probability of vehicle survival after i years of service
$(ER)_i$	= Emission rate, g/mi in year i of a vehicle's operational life
K	= Conversion factor, 1.102×10^{-6} tons/gram
i	= Vehicle years of operation, counting from 1 to 25

For NOx and exhaust NMHC, we generated discounted lifetime tonnage values for each vehicle class (LDV, LDT1, LDT2, LDT3, LDT4) using the above equation. This was done separately for the baseline and control cases. The baseline case included the NLEV vehicle program (LEV for LDV, LDT1 and LDT2; Tier 1 for LDT3 and LDT4) and the in-use fuel program (RFG in the appropriate areas, modeled at 150 ppm sulfur for the summer; conventional gasoline in the remaining areas, modeled at 330 ppm sulfur). The control case entailed the Tier 2 vehicle program (0.07 g NOx/mi and 0.09 g NMHC/mi for all vehicle classes) and fuel program (30 ppm nationwide). Baseline and controlled sulfur levels also included the maximum sulfur levels that would be seen by a vehicle over its lifetime in order to estimate the impacts of catalyst irreversibility as described in Section VI.C.2 below. Thus the actual number of sulfur cases was four: two for the average baseline and control sulfur levels, and two more for the maximum baseline and control sulfur levels. For each permutation of vehicle and fuel program, tonnage estimates were also developed for IM and non-IM areas to allow generation of a nationwide composite tonnage estimate. The tonnage values that we calculated according to this procedure are presented in Appendix VI-A.

Before using the tonnage values to calculate the cost-effectiveness of our proposed program, it was necessary for us to combine the values for IM vs. no-IM areas and RFG vs. conventional gasoline areas in an effort to represent the national scope of our proposed program. The weighting factors were based on an analysis of the fraction of the population in the 47 state area (U.S. excluding California, Alaska, and Hawaii) which was located within or outside of IM and RFG areas[5]. We also made a distinction between summer and winter RFG, since summer-grade Phase II RFG having approximately 150 ppm sulfur will be used for only 40 percent of the year, while winter-grade Phase II RFG having approximately 300 ppm sulfur will be used for the remaining 60 percent of the year. 1998 population data was used to determine these population fractions by state, and then nationwide weighting factors were produced from the sum of these fractional by-state populations. The geographical results are shown in Table VI-3.

For evaporative NMHC, we based the baseline tonnage values on gram/mile emissions projected by MOBILE5b. To model our control case, we projected the gram/mile emissions using the version of MOBILE5b which was modified to reflect the benefits of our proposed Tier 2 controls. We used gram/mile emission factors from 2030 to reflect a baseline fleet consisting entirely of Enhanced Evaporative vehicles, and a control fleet consisting of essentially all Tier 2 vehicles[6]. The evaporative tonnage values are presented in Appendix VI-B.

Table VI-3. Weighting Factors for NOx and NMHC Lifetime Tonnage Values

RFG program area?	*IM program area?*	*Fraction of population*
Yes	Yes	0.248
Yes	No	0.019
No	Yes	0.228
No	No	0.505

The final step before calculating the cost-effectiveness of our proposed program was to weight the discounted lifetime tonnage values for each vehicle class by their respective fraction of the fleet. These fractions were developed based on our projection that LDT sales will stabilize at 60 percent of the light-duty market by 2008. This value is based on sales data projected by auto manufacturers for 1998 model year certification. Table VI-4 presents the final weighting factors we used to develop fleet-average tonnage values.

Table VI-4. Vehicle Class Sales Weighting Factors

LDV	0.4
LDT1	0.11
LDT2	0.34
LDT3	0.10
LDT4	0.05

The final discounted lifetime tonnage values in the absence of sulfur irreversibility effects for an average fleet vehicle meeting either the standards for NLEV or our proposed Tier 2 standards are shown in Tables VI-5 and VI-6, respectively.

Table VI-5. Fleet-average, Per-vehicle Discounted Lifetime Tons for the NLEV Baseline

Sulfur (ppm)	*NOx (tons)*	*Exhaust NMHC (tons)*	*Evap NMHC (tons)*
800[b]	0.13925	0.03623	0.04192
305	0.11295	0.03285	0.04192

Table VI-6. Fleet-average, Per-vehicle Discounted Lifetime Tons for Proposed Tier 2 Standards

Sulfur (ppm)	*NOx (tons)*	*Exhaust NMHC (tons)*	*Evap NMHC (tons)*
80	0.03557	0.02366	0.03887
30	0.02738	0.02247	0.03887

The values in Tables VI-5 and VI-6 were not used in the cost-effectiveness calculations directly. Instead, the effects of irreversibility were first calculated according to the methodology described

[b] Tonnage values at 800 ppm and 80 ppm sulfur were used for estimating the impacts of irreversibility. See Section VI.C.2 for details.

in Section VI.C.2 below using the tonnage values from the tables above.

2. Irreversibility

As described in Appendix B, we believe that vehicles meeting the SFTP and/or NLEV standards will exhibit an increased tendency towards sulfur poisoning of their catalysts. As a result of sulfur poisoning, catalyst efficiency is reduced and emissions increase. Since all vehicles are currently certified on low sulfur fuel, current in-use emissions can be expected to be higher than certification levels.

The increased emissions that result when an SFTP-compliant NLEV or Tier 2 vehicle is run on high sulfur fuel is a function of the "sulfur sensitivity" of the catalyst. This aspect of sulfur poisoning has been taken into account in our cost-effectiveness analysis by virtue of the fact that the change in lifetime tons reduced is a function of our proposed gasoline sulfur standard. The impacts of the sulfur sensitivities on emissions for pre-SFTP and post-SFTP compliant vehicles are described in an EPA Technical Report[7].

However, one aspect of sulfur poisoning requires special treatment in our cost-effectiveness analysis. In SFTP-compliant vehicles, some sulfur poisoning due to the use of high sulfur fuel often extends well beyond the time that high sulfur fuel is actually used. When an SFTP-compliant vehicle returns to using low sulfur gasoline after having been operated on high sulfur fuel, a degree of poisoning remains. This effect is termed "irreversibility," and is described in detail in Appendix B. We have estimated that the irreversibility effect for SFTP-compliant vehicles will be about 50 percent, meaning that 50 percent of the emission reductions that would otherwise occur when changing from high to low sulfur fuel are lost due to permanent sulfur poisoning of the catalyst. That is to say, 50 percent of the sensitivity effect is permanent or “irreversible” regardless of the fuel sulfur level.

Since our cost-effectiveness analysis makes use of emissions summed over the life of a vehicle, we must account for the fact that there may have been hundreds of refuelings in that time frame with repeated switches between low and high sulfur fuel. Since the higher sulfur fuels will be widely available, we expect vehicles to be exposed to such fuels early in their lives. As a result, the irreversibility effect will be present for most of these vehicles' lifetimes. Irreversibility effects on lifetime emissions can then be calculated as the difference between lifetime emissions at high sulfur fuel and lifetime emissions at the average fuel sulfur level.

While it is possible that the irreversibility effect can be reduced or eliminated under certain driving conditions, such as high temperature/high load driving, we believe that this is unlikely for SFTP-compliant vehicles. The data regarding catalyst cleanup conditions for future vehicles is quite limited. Lacking data to support the recovery of full catalyst functionality, our analysis treats irreversibility as a permanent effect.

Under our proposed gasoline sulfur program, the average sulfur level will be 30 ppm and the maximum allowable level will be 80 ppm. Per-vehicle lifetime emissions at these two sulfur levels were used to determine the effect of irreversibility on Tier 2 vehicles. The Tier 2 lifetime tonnage values for NOx and exhaust NMHC at 30 ppm, which included the effects of irreversibility and which was actually used in our cost-effectiveness analysis, was calculated from the following equation:

$$ILE_{30} = (IE) \bullet (LE_{80} - LE_{30}) + LE_{30}$$

Where:

ILE_{30} = Irreversibility-impacted, discounted lifetime emissions of Tier 2 vehicles at 30 ppm sulfur in tons/vehicle, for each vehicle class
IE = Irreversibility impact, 0.50
LE_{80} = Discounted lifetime emissions of Tier 2 vehicles at 80 ppm sulfur in tons/vehicle, for each vehicle class
LE_{30} = Discounted lifetime emissions of Tier 2 vehicles at 30 ppm sulfur in tons/vehicle, for each vehicle class

For the NLEV vehicles forming our baseline, the average sulfur level was established as 305 ppm as described in Section VI.A.3 above. Apart from an ASTM maximum allowable value of 1000 ppm, there is no regulated in-use maximum value for gasoline sulfur. However, after the year 2000, we project that more than 95 percent of gasoline will contain sulfur levels below 800 ppm. We have therefore chosen 800 as the maximum sulfur level on which NLEV vehicles will be operated. It could be argued that 1000 ppm is a more appropriate value to represent the maximum (or even higher, as a few in-use batches of gasoline exceed the ASTM limit). We believe that a maximum of 800 ppm is more representative of the maximum sulfur level that the average NLEV vehicle will be operated on, since very few vehicles will ever see sulfur levels as high as 1000 ppm.

Per-vehicle lifetime emissions at 305 ppm and 800 ppm were used to determine the effect of irreversibility on vehicles meeting NLEV standards. Unlike for Tier 2 vehicles, however, NLEV standards only apply to LDV, LDT1, and LDT2, while LDT3 and LDT4 meet Tier 1 standards as well as the SFTP. As discussed in Appendix B, we believe that irreversibility applies to any SFTP-compliant vehicle, including Tier 1 vehicles produced after the year 2000. Thus the calculations followed the same procedure as that used for Tier 2 vehicles:

$$ILE_{305} = (IE) \bullet (LE_{800} - LE_{305}) + LE_{305}$$

Where:

ILE_{305} = Irreversibility-impacted, discounted lifetime emissions of SFTP-complaint NLEV vehicles at 305 ppm sulfur in tons/vehicle, for each vehicle class
IE = Irreversibility impact, 0.50
LE_{800} = Discounted lifetime emissions of NLEV vehicles at 800 ppm sulfur in tons/vehicle, for each vehicle class
LE_{305} = Discounted lifetime emissions of NLEV vehicles at 305 ppm sulfur in

tons/vehicle, for each vehicle class

After assessing the impact of irreversibility on both Tier 2 and NLEV vehicles, we were able to develop a final set of discounted lifetime tonnage values that were actually used in our cost-effectiveness analysis. These values are given in Table VI-7.

Table VI-7. Fleet-average, Per-vehicle Discounted Lifetime Tons Used in Cost-effectiveness Analysis

	NOx (tons)	*Exhaust NMHC (tons)*	*Evap NMHC (tons)*	*Total NOx + NMHC (tons)*
Baseline: NLEV at 305 ppm	0.12610	0.03454	0.04192	0.20256
Proposal: Tier 2 at 30 ppm	0.03148	0.02307	0.04020	0.09475

3. Primary Particulate Matter

Vehicles meeting our proposed standards will produce reductions in both primary and secondary particulate matter. As described in Section VI.B.3 above, we are accounting for reductions in primary (sulfate) PM in our cost-effectiveness analysis. Although secondary PM reductions are not being accounted for in our cost-effectiveness analysis, they have been included in our analysis of the health and welfare benefits of our proposed program, as described in Section VII.

Primary PM emission reductions result from the removal of sulfur in gasoline, which produces a commensurate reduction in the amount of sulfate PM emitted from the tailpipe. To calculate the reduction, we have assumed that sulfate PM accounts for 1 percent of all sulfur exiting the tailpipe on a molar basis. Primary sulfate PM exists almost entirely as sulfuric acid, and is generally hydrated. We have assumed seven hydrations, consistent with the approach taken in the development of EPA's NON-ROAD emissions model.

Discounted lifetime tons of primary PM reduced as a result of our proposed gasoline sulfur standard are calculated according to the following equation:

$$LE = \sum [\{(AVMT)_i \bullet (SURVIVE)_i \div (FE) \bullet (D) \bullet (SUL) \bullet (F) \bullet (MC) \bullet (K)\}/(1.07)^{i-1}]$$

Where:

LE	= Discounted lifetime emissions of primary PM in tons/vehicle
$(AVMT)_i$	= Annual vehicle miles traveled in year i of a vehicle's operational life
$(SURVIVE)_i$	= Fraction of vehicles still operating after i years of service
FE	= Fuel economy by vehicle class (see Section VI.B.4)
D	= Density of gasoline, 6.17 lb/gal
SUL	= Change in gasoline sulfur concentration, 2.75×10^{-4} lb sulfur/lb fuel (275 ppm)
F	= Fraction of total sulfur which exits the tailpipe as primary PM, 0.01
MC	= Molar conversion factor, 7 lb sulfuric acid per lb sulfur
K	= Conversion factor, 5.0×10^{-4} tons/lb
i	= Vehicle years of operation, counting from 1 to 25

After applying the above equation separately for each vehicle class and weighting the resulting tonnage values according to the factors presented in Table VI-4, we determined that the fleet-average, per-vehicle discounted lifetime tons of primary PM reduced is 0.000396. This is the value that was used to determine the PM-based credit that was applied to the total costs as described in Section VI.B.3 and summarized in Table VI-2.

4. Sulfur Dioxide

The sulfur contained in gasoline exists the tailpipe as either sulfuric acid, a component of primary particulate matter, or as sulfur dioxide (SO_2). As described in Section VI.C.2 above, we have assumed that sulfate PM, as hydrated sulfuric acid, accounts for 1 percent of all sulfur exiting the tailpipe on a molar basis. Thus the remaining 99 percent of sulfur exiting the tailpipe is in the form of SO_2.

Discounted lifetime tons of SO_2 reduced as a result of our proposed gasoline sulfur standard are calculated according to the following equation:

$$LE = \sum [\{(AVMT)_i \bullet (SURVIVE)_i \div (FE) \bullet (D) \bullet (SUL) \bullet (F) \bullet (MC) \bullet (K)\}/(1.07)^{i-1}]$$

Where:

LE	= Discounted lifetime emissions of SO_2 in tons/vehicle
$(AVMT)_i$	= Annual vehicle miles traveled in year i of a vehicle's operational life
$(SURVIVE)_i$	= Fraction of vehicles still operating after i years of service
FE	= Fuel economy by vehicle class (see Section VI.B.4)
D	= Density of gasoline, 6.17 lb/gal
SUL	= Change in gasoline sulfur concentration, 2.75×10^{-4} lb sulfur/lb fuel (275 ppm)
F	= Fraction of total sulfur which exits the tailpipe as SO_2, 0.99
MC	= Molar conversion factor, 2 lb SO_2 per lb sulfur
K	= Conversion factor, 5.0×10^{-4} tons/lb

i = Vehicle years of operation, counting from 1 to 25

After applying the above equation separately for each vehicle class and weighting the resulting tonnage values according to the factors presented in Table VI-4, we determined that the fleet-average, per-vehicle discounted lifetime tons of SO_2 reduced is 0.01119. This is the value that was used to determine the SO_2-based credit that was applied to the total costs as described in Section VI.B.3 and summarized in Table VI-2.

D. Results

We calculated the cost-effectiveness of our proposed standards for Tier 2 exhaust, Tier 2 evaporative, and gasoline sulfur as the total per-vehicle, discounted lifetime costs divided by the total per-vehicle, discounted lifetime tons reduced. Costs are given in Table VI-2. The tons reduced are calculated from the values in Table VI-7 as the difference between our NLEV baseline at our baseline sulfur level of 305 ppm, and our proposed Tier 2 standards at our proposed sulfur standard of 30 ppm. The results are given in Table VI-8.

Table VI-8. Cost-effectiveness of the Proposed Standards

	Credited costs ($)	*Uncredited costs ($)*	*Tons NOx+NMHC*	*Credited $/ton*	*Uncredited $/ton*
Near term	172.37	230.06	0.10781	1599	2134
Long term	130.74	188.43	0.10781	1213	1748

We also evaluated the cost effectiveness of a number of alternative control options using the methodology described in this Section. The options evaluated were:

- The proposed Tier 2 emission standards with no reduction in gasoline sulfur levels;

- The proposed Tier 2 emission standards with the sulfur controls proposed by API and NPRA, which include average sulfur standards of 150 ppm in the NOx Control Region (nominally the eastern two-thirds of the U.S.) and 300 ppm elsewhere (i.e., the West) starting in 2004;

- The proposed Tier 2 emission standards with average sulfur standard of 30 ppm in API/NPRA NOx Control Region and 150 ppm in the West starting in 2004;

- The proposed Tier 2 emission standards with an 80 ppm nationwide sulfur standard starting in 2004;

- The proposed 30 ppm nationwide sulfur standard with California Phase 2 LEV emission standards (excluding the ZEV mandate); because these standards change from year to year, we chose to evaluate the 2010 model year standards;

All of these alternative control options are evaluated relative to the same baseline which was used to evaluate the cost effectiveness of the proposed Tier 2 and sulfur standards. The results are shown in Table VI-9 below.

Table VI-9. Alternative program options evaluated by EPA

	Credited costs ($)	*Uncredited costs ($)*	*Tons NOx+NMHC*	*Credited $/ton*	*Uncredited $/ton*
Tier 2 vehicle standards with 80 ppm nationwide					
Near term	155.37	202.58	0.09921	1566	2042
Long term	115.63	162.84	0.09921	1166	1641
Tier 2 vehicle standards with no change in sulfur					
Near term	128.14	128.14	0.07319	1751	1751
Long term	93.57	93.57	0.07319	1278	1278
Tier 2 vehicle standards with 150 ppm in API region, 300 ppm in non-API region					
Near term	136.80	161.81	0.08719	1569	1856
Long term	99.89	124.90	0.08719	1146	1433
Tier 2 vehicle standards with 30 ppm in API region, 150 ppm in non-API region					
Near term	165.20	216.57	0.10263	1610	2110
Long term	124.51	175.88	0.10263	1213	1714
California LEV-II NMOG emission standards with 30 ppm nationwide					
Near term	205.02	262.70	0.11168	1836	2352
Long term	158.75	216.43	0.11168	1421	1938

As can be seen, the cost effectiveness of the five alternatives are all quite similar to that of the proposed program. The long-term credited cost per ton of the alternatives are all within $50 per ton of that for the proposed program, with the exception of the California LEV-II NMOG standards. The long-term credited cost effectiveness of this program is roughly $150 per ton higher than that of the proposed program. For reasons cited elsewhere in this Draft RIA and in the preamble to the proposed rule, EPA chose not to propose any of these alternative control programs in lieu of the proposed standards.

Because the primary purpose of cost-effectiveness is to compare our proposed program to alternative programs, we made a comparison between the values in Table VI-8 and the cost-effectiveness of other programs. Table VI-10 summarizes the cost effectiveness of several recent EPA actions for controlled emissions from mobile sources.

Table VI-10. Cost-effectiveness of Previously Implemented Mobile Source Programs (Costs Adjusted to 1997 Dollars)

Program	*$/ton NOx+NMHC*
2004 Highway HD Diesel stds	300
Non-road Diesel engine stds	410-650
Tier 1 vehicle controls	1,980-2,690[b]
NLEV	1,859
Marine SI engines	1,128-1,778
On-board diagnostics	2,228

By comparing the values from Table VI-8 to those in Table VI-10, we can see that the cost effectiveness of the Tier 2/gasoline sulfur standards falls within the range of these other programs. Engine-based standards (the 2004 highway heavy-duty diesel standards, the non-road diesel engine standards and the marine spark-ignited engine standards) have generally been less costly than our proposed Tier 2/gasoline sulfur standards. Vehicle standards, most similar to today's proposal, have comparable or higher values than our proposed Tier 2/gasoline sulfur program.

The primary advantage of making comparisons to previously implemented programs is that their cost-effectiveness values were based on a rigorous analysis and are generally accepted as representative of the efficiency with which those programs reduce emissions. Unfortunately, previously implemented programs can be poor comparisons because they may not be

[b] Cost-effectiveness of Tier 1 standards was originally calculated separately for NOx and NMHC. A combined cost-effectiveness was recalculated for our proposal. See internal memorandum from David Korotney to Docket A-97-10, "Calculation of Tier 1 vehicle cost-effectiveness in terms of $/ton NOx+NMHC," document number II-B-03.

representative of the cost-effectiveness of potential future programs. For instance, it is tempting to look at the engine standards and conclude that more reductions at a similar low cost effectiveness should still be available. This is especially true for the two largest categories (highway and non-road diesel engines) where new standards have been adopted that were highly cost effective. However, cost effectiveness was not a limiting consideration in either case. Rather, the level of the standards selected was based on technical feasibility in the time available.

We do not believe that significant further control is available from highway or non-road diesel engines through more stringent standards at the cost effectiveness levels shown in Table VI-10. Based on current knowledge, the next generation of controls for these diesel engines would require advanced after-treatment devices, still in the research and development phase. Such controls have not yet been employed and when they become available will be more costly and will have difficulty functioning without changes to diesel fuel.

On the vehicle side, the last two sets of standards were Tier 1 and NLEV, which had cost effectiveness comparable to or higher than our proposed Tier 2/gasoline sulfur standards. Compared to engines, these levels reflect the advanced (and more expensive) state of vehicle control technology, where standards have been in effect for a much longer period than for engines. Based on these results, Tier 2/gasoline sulfur appears to be a logical and consistent next step in vehicle control.

The most complete source of information on the cost-effectiveness of potential future programs is the rulemaking which revised the PM and ozone National Ambient Air Quality Standards (NAAQS). The Regulatory Impact Analysis (RIA) associated with that rulemaking contained a listing of potential future emission control programs and their cost-effectiveness[8]. The listing categorizes control programs by mobile, point, and area source strategies for a total of 236 potential future programs. Although the majority of the programs in this list would most likely be implemented on a local or regional basis, they still provide the most complete information available on alternative programs and their associated cost-effectiveness.

Of the 236 potential future programs in the NAAQS RIA, 112 produced NOx reductions with an average cost-effectiveness of $13,000/ton, while 55 programs produced NMHC reductions with an average cost-effectiveness of $5,000/ton. These values confirm that future controls will be more expensive than past controls. In fact, for the purposes of evaluating the capability of potential future controls for bringing all areas into attainment, an upper limit of $10,000/ton was established. As a result of the analyses conducted in the context of the NAAQS revisions rulemaking, it was determined that some areas would be willing to pay up to $10,000/ton for local control measures in order to achieve attainment.

We recognize that the cost effectiveness calculated for our proposed program is not strictly comparable to the $10,000/ton limit established in the NAAQS analyses since the technologies identified there can be targeted at the specific nonattainment areas of concern, while the proposed Tier 2/gasoline sulfur program would apply nationwide. However, we are not using cost effectiveness to portray Tier 2 as a control strategy to select as an alternative to local controls because of its lower cost effectiveness. Rather, the program we are proposing today is likely one of several programs, both national and local in nature, that will be necessary for attainment and maintenance of the NAAQS.

In summary, given the array of controls that will have to be implemented to make progress toward attaining and maintaining the NAAQS, we believe that the weight of the evidence from alternative means of providing substantial NOx + NMHC emission reductions indicates that our Tier 2/gasoline sulfur proposal is cost-effective. This is true from the perspective of other mobile source control programs or from the perspective of other stationary source technologies that might be considered.

APPENDIX VI-A : Discounted Lifetime Tonnage Values for Exhaust Emissions

Standard	Veh clas	IM case	Sulfur	Fuel	NOx tons	NMHC tons
NLEV	LDT1	IM	30	Conventional	0.04614	0.01839
NLEV	LDT1	IM	80	Conventional	0.06296	0.01989
NLEV	LDT1	IM	330	Conventional	0.10032	0.02252
NLEV	LDT1	IM	800	Conventional	0.13343	0.02424
NLEV	LDT1	IM	30	RFG	0.04494	0.01565
NLEV	LDT1	IM	80	RFG	0.06132	0.01694
NLEV	LDT1	IM	150	RFG	0.07523	0.01787
NLEV	LDT1	IM	300	RFG	0.09463	0.01901
NLEV	LDT1	IM	800	RFG	0.12953	0.02061
NLEV	LDT1	No IM	30	Conventional	0.06646	0.03540
NLEV	LDT1	No IM	80	Conventional	0.08716	0.03669
NLEV	LDT1	No IM	330	Conventional	0.13312	0.03906
NLEV	LDT1	No IM	800	Conventional	0.18824	0.04059
NLEV	LDT1	No IM	30	RFG	0.06478	0.03000
NLEV	LDT1	No IM	80	RFG	0.08495	0.03110
NLEV	LDT1	No IM	150	RFG	0.10209	0.03192
NLEV	LDT1	No IM	300	RFG	0.12597	0.03297
NLEV	LDT1	No IM	800	RFG	0.16619	0.03424
NLEV	LDT2	IM	30	Conventional	0.07705	0.02205
NLEV	LDT2	IM	80	Conventional	0.08783	0.02329
NLEV	LDT2	IM	330	Conventional	0.10639	0.02535
NLEV	LDT2	IM	800	Conventional	0.11983	0.02668
NLEV	LDT2	IM	30	RFG	0.07503	0.01878
NLEV	LDT2	IM	80	RFG	0.08552	0.01984
NLEV	LDT2	IM	150	RFG	0.09307	0.02059
NLEV	LDT2	IM	300	RFG	0.10225	0.02147
NLEV	LDT2	IM	800	RFG	0.11660	0.02271
NLEV	LDT2	No IM	30	Conventional	0.09894	0.03943
NLEV	LDT2	No IM	80	Conventional	0.11092	0.04051
NLEV	LDT2	No IM	330	Conventional	0.13155	0.04241
NLEV	LDT2	No IM	800	Conventional	0.14896	0.04306
NLEV	LDT2	No IM	30	RFG	0.09642	0.03344
NLEV	LDT2	No IM	80	RFG	0.10809	0.03436
NLEV	LDT2	No IM	150	RFG	0.11650	0.03502
NLEV	LDT2	No IM	300	RFG	0.12671	0.03586
NLEV	LDT2	No IM	800	RFG	0.14218	0.03688
NLEV	LDT3	IM	30	Conventional	0.15696	0.05429
NLEV	LDT3	IM	80	Conventional	0.15929	0.05585
NLEV	LDT3	IM	330	Conventional	0.17147	0.06451
NLEV	LDT3	IM	800	Conventional	0.18512	0.07818
NLEV	LDT3	IM	30	RFG	0.15282	0.04632
NLEV	LDT3	IM	80	RFG	0.15508	0.04765
NLEV	LDT3	IM	150	RFG	0.15830	0.04960
NLEV	LDT3	IM	300	RFG	0.16546	0.05410
NLEV	LDT3	IM	800	RFG	0.17755	0.06646
NLEV	LDT3	No IM	30	Conventional	0.18307	0.07525
NLEV	LDT3	No IM	80	Conventional	0.18545	0.07659
NLEV	LDT3	No IM	330	Conventional	0.19794	0.08400
NLEV	LDT3	No IM	800	Conventional	0.22195	0.09850
NLEV	LDT3	No IM	30	RFG	0.17836	0.06396
NLEV	LDT3	No IM	80	RFG	0.18068	0.06510
NLEV	LDT3	No IM	150	RFG	0.18399	0.06677

NLEV	LDT3	No IM	300	RFG	0.19134	0.07062
NLEV	LDT3	No IM	800	RFG	0.20478	0.08046
NLEV	LDT4	IM	30	Conventional	0.23321	0.06443
NLEV	LDT4	IM	80	Conventional	0.23669	0.06632
NLEV	LDT4	IM	330	Conventional	0.25494	0.07682
NLEV	LDT4	IM	800	Conventional	0.28329	0.09441
NLEV	LDT4	IM	30	RFG	0.22703	0.05498
NLEV	LDT4	IM	80	RFG	0.23042	0.05659
NLEV	LDT4	IM	150	RFG	0.23525	0.05895
NLEV	LDT4	IM	300	RFG	0.24598	0.06442
NLEV	LDT4	IM	800	RFG	0.27546	0.08026
NLEV	LDT4	No IM	30	Conventional	0.26188	0.08646
NLEV	LDT4	No IM	80	Conventional	0.26534	0.08807
NLEV	LDT4	No IM	330	Conventional	0.28349	0.09702
NLEV	LDT4	No IM	800	Conventional	0.30934	0.11431
NLEV	LDT4	No IM	30	RFG	0.25512	0.07351
NLEV	LDT4	No IM	80	RFG	0.25849	0.07489
NLEV	LDT4	No IM	150	RFG	0.26330	0.07690
NLEV	LDT4	No IM	300	RFG	0.27397	0.08155
NLEV	LDT4	No IM	800	RFG	0.30272	0.09452
NLEV	LDV	IM	30	Conventional	0.03043	0.01124
NLEV	LDV	IM	80	Conventional	0.04183	0.01224
NLEV	LDV	IM	330	Conventional	0.06714	0.01400
NLEV	LDV	IM	800	Conventional	0.08982	0.01517
NLEV	LDV	IM	30	RFG	0.02963	0.00957
NLEV	LDV	IM	80	RFG	0.04073	0.01043
NLEV	LDV	IM	150	RFG	0.05016	0.01106
NLEV	LDV	IM	300	RFG	0.06330	0.01182
NLEV	LDV	IM	800	RFG	0.08723	0.01291
NLEV	LDV	No IM	30	Conventional	0.03939	0.01892
NLEV	LDV	No IM	80	Conventional	0.05250	0.01983
NLEV	LDV	No IM	330	Conventional	0.08161	0.02146
NLEV	LDV	No IM	800	Conventional	0.11664	0.02264
NLEV	LDV	No IM	30	RFG	0.03839	0.01605
NLEV	LDV	No IM	80	RFG	0.05116	0.01683
NLEV	LDV	No IM	150	RFG	0.06201	0.01740
NLEV	LDV	No IM	300	RFG	0.07713	0.01812
NLEV	LDV	No IM	800	RFG	0.10329	0.01903
Tier 2	LDT1	IM	30	Conventional	0.02183	0.01839
Tier 2	LDT1	IM	80	Conventional	0.02903	0.01989
Tier 2	LDT1	IM	330	Conventional	0.04500	0.02252
Tier 2	LDT1	IM	800	Conventional	0.05863	0.02470
Tier 2	LDT1	IM	30	RFG	0.02128	0.01565
Tier 2	LDT1	IM	80	RFG	0.02828	0.01694
Tier 2	LDT1	IM	150	RFG	0.03424	0.01787
Tier 2	LDT1	IM	300	RFG	0.04253	0.01901
Tier 2	LDT1	IM	800	RFG	0.05683	0.02055
Tier 2	LDT1	No IM	30	Conventional	0.04163	0.03540
Tier 2	LDT1	No IM	80	Conventional	0.05338	0.03669
Tier 2	LDT1	No IM	330	Conventional	0.07948	0.03906
Tier 2	LDT1	No IM	800	Conventional	0.11031	0.04041
Tier 2	LDT1	No IM	30	RFG	0.04060	0.03000
Tier 2	LDT1	No IM	80	RFG	0.05206	0.03110
Tier 2	LDT1	No IM	150	RFG	0.06180	0.03192
Tier 2	LDT1	No IM	300	RFG	0.07537	0.03297
Tier 2	LDT1	No IM	800	RFG	0.09735	0.03416
Tier 2	LDT2	IM	30	Conventional	0.02033	0.01832
Tier 2	LDT2	IM	80	Conventional	0.02685	0.01982
Tier 2	LDT2	IM	330	Conventional	0.04133	0.02242

Tier 2	LDT2	IM	800	Conventional	0.05357	0.02459
Tier 2	LDT2	IM	30	RFG	0.01982	0.01559
Tier 2	LDT2	IM	80	RFG	0.02617	0.01687
Tier 2	LDT2	IM	150	RFG	0.03157	0.01780
Tier 2	LDT2	IM	300	RFG	0.03909	0.01893
Tier 2	LDT2	IM	800	RFG	0.05191	0.02045
Tier 2	LDT2	No IM	30	Conventional	0.04101	0.03535
Tier 2	LDT2	No IM	80	Conventional	0.05236	0.03663
Tier 2	LDT2	No IM	330	Conventional	0.07756	0.03898
Tier 2	LDT2	No IM	800	Conventional	0.10723	0.04033
Tier 2	LDT2	No IM	30	RFG	0.04000	0.02996
Tier 2	LDT2	No IM	80	RFG	0.05106	0.03105
Tier 2	LDT2	No IM	150	RFG	0.06047	0.03187
Tier 2	LDT2	No IM	300	RFG	0.07357	0.03291
Tier 2	LDT2	No IM	800	RFG	0.09464	0.03413
Tier 2	LDT3	IM	30	Conventional	0.02730	0.02130
Tier 2	LDT3	IM	80	Conventional	0.03626	0.02302
Tier 2	LDT3	IM	330	Conventional	0.05614	0.02602
Tier 2	LDT3	IM	800	Conventional	0.07307	0.02848
Tier 2	LDT3	IM	30	RFG	0.02661	0.01813
Tier 2	LDT3	IM	80	RFG	0.03533	0.01960
Tier 2	LDT3	IM	150	RFG	0.04274	0.02066
Tier 2	LDT3	IM	300	RFG	0.05307	0.02197
Tier 2	LDT3	IM	800	RFG	0.07083	0.02369
Tier 2	LDT3	No IM	30	Conventional	0.05087	0.04114
Tier 2	LDT3	No IM	80	Conventional	0.06519	0.04260
Tier 2	LDT3	No IM	330	Conventional	0.09700	0.04528
Tier 2	LDT3	No IM	800	Conventional	0.13467	0.04681
Tier 2	LDT3	No IM	30	RFG	0.04961	0.03486
Tier 2	LDT3	No IM	80	RFG	0.06358	0.03611
Tier 2	LDT3	No IM	150	RFG	0.07544	0.03703
Tier 2	LDT3	No IM	300	RFG	0.09198	0.03822
Tier 2	LDT3	No IM	800	RFG	0.11874	0.03979
Tier 2	LDT4	IM	30	Conventional	0.02970	0.02152
Tier 2	LDT4	IM	80	Conventional	0.03954	0.02326
Tier 2	LDT4	IM	330	Conventional	0.06139	0.02631
Tier 2	LDT4	IM	800	Conventional	0.08008	0.02883
Tier 2	LDT4	IM	30	RFG	0.02894	0.01831
Tier 2	LDT4	IM	80	RFG	0.03853	0.01981
Tier 2	LDT4	IM	150	RFG	0.04667	0.02089
Tier 2	LDT4	IM	300	RFG	0.05802	0.02221
Tier 2	LDT4	IM	800	RFG	0.07763	0.02398
Tier 2	LDT4	No IM	30	Conventional	0.05402	0.04138
Tier 2	LDT4	No IM	80	Conventional	0.06935	0.04286
Tier 2	LDT4	No IM	330	Conventional	0.10338	0.04559
Tier 2	LDT4	No IM	800	Conventional	0.14375	0.04714
Tier 2	LDT4	No IM	30	RFG	0.05268	0.03506
Tier 2	LDT4	No IM	80	RFG	0.06763	0.03633
Tier 2	LDT4	No IM	150	RFG	0.08032	0.03728
Tier 2	LDT4	No IM	300	RFG	0.09802	0.03848
Tier 2	LDT4	No IM	800	RFG	0.12673	0.04006
Tier 2	LDV	IM	30	Conventional	0.01364	0.01124
Tier 2	LDV	IM	80	Conventional	0.01831	0.01224
Tier 2	LDV	IM	330	Conventional	0.02868	0.01400
Tier 2	LDV	IM	800	Conventional	0.03766	0.01556
Tier 2	LDV	IM	30	RFG	0.01328	0.00957
Tier 2	LDV	IM	80	RFG	0.01783	0.01043
Tier 2	LDV	IM	150	RFG	0.02170	0.01106
Tier 2	LDV	IM	300	RFG	0.02709	0.01182

Tier 2	LDV	IM	800	RFG	0.03653	0.01293
Tier 2	LDV	No IM	30	Conventional	0.02237	0.01892
Tier 2	LDV	No IM	80	Conventional	0.02905	0.01983
Tier 2	LDV	No IM	330	Conventional	0.04389	0.02146
Tier 2	LDV	No IM	800	Conventional	0.06155	0.02244
Tier 2	LDV	No IM	30	RFG	0.02181	0.01605
Tier 2	LDV	No IM	80	RFG	0.02832	0.01683
Tier 2	LDV	No IM	150	RFG	0.03386	0.01740
Tier 2	LDV	No IM	300	RFG	0.04157	0.01812
Tier 2	LDV	No IM	800	RFG	0.05435	0.01930

APPENDIX VI-B : Discounted Lifetime Tonnage Values for Evaporative Emissions

Standard	Veh class	IM case	Fuel	NMHC tons
2.0 gpt enhanced	LDT1	IM	Conventional	0.02835
2.0 gpt enhanced	LDT1	IM	RFG	0.01793
2.0 gpt enhanced	LDT1	No IM	Conventional	0.06791
2.0 gpt enhanced	LDT1	No IM	RFG	0.03537
2.0 gpt enhanced	LDT2	IM	Conventional	0.02835
2.0 gpt enhanced	LDT2	IM	RFG	0.01793
2.0 gpt enhanced	LDT2	No IM	Conventional	0.06791
2.0 gpt enhanced	LDT2	No IM	RFG	0.03537
2.0 gpt enhanced	LDT3	IM	Conventional	0.03216
2.0 gpt enhanced	LDT3	IM	RFG	0.01972
2.0 gpt enhanced	LDT3	No IM	Conventional	0.08730
2.0 gpt enhanced	LDT3	No IM	RFG	0.04301
2.0 gpt enhanced	LDT4	IM	Conventional	0.03216
2.0 gpt enhanced	LDT4	IM	RFG	0.01972
2.0 gpt enhanced	LDT4	No IM	Conventional	0.08730
2.0 gpt enhanced	LDT4	No IM	RFG	0.04301
2.0 gpt enhanced	LDV	IM	Conventional	0.02184
2.0 gpt enhanced	LDV	IM	RFG	0.01208
2.0 gpt enhanced	LDV	No IM	Conventional	0.04722
2.0 gpt enhanced	LDV	No IM	RFG	0.02268
Tier 2	LDT1	IM	Conventional	0.02612
Tier 2	LDT1	IM	RFG	0.01622
Tier 2	LDT1	No IM	Conventional	0.06595
Tier 2	LDT1	No IM	RFG	0.03389
Tier 2	LDT2	IM	Conventional	0.02612
Tier 2	LDT2	IM	RFG	0.01622
Tier 2	LDT2	No IM	Conventional	0.06595
Tier 2	LDT2	No IM	RFG	0.03389
Tier 2	LDT3	IM	Conventional	0.02994
Tier 2	LDT3	IM	RFG	0.01797
Tier 2	LDT3	No IM	Conventional	0.08551
Tier 2	LDT3	No IM	RFG	0.04168
Tier 2	LDT4	IM	Conventional	0.02994
Tier 2	LDT4	IM	RFG	0.01797
Tier 2	LDT4	No IM	Conventional	0.08551
Tier 2	LDT4	No IM	RFG	0.04168
Tier 2	LDV	IM	Conventional	0.02028
Tier 2	LDV	IM	RFG	0.01101
Tier 2	LDV	No IM	Conventional	0.04567
Tier 2	LDV	No IM	RFG	0.02158

Chapter VI References:

1. U.S. EPA; Review of NAAQS for Ozone, Assessment of Scientific and Technical Information, Office of Air Quality Planning and Standards Staff Paper; document number: EPA-452\R-96-007

2. "Final Regulatory Impact Analysis: Control of Emissions of Air Pollution from Highway Heavy-Duty Engines." September 16, 1997. Alan Stout, U.S. EPA, OAR/OMS/EPCD.

3. "Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines; Particulate Emission Regulations for 1993 Model Year Buses, Particulate Emission Regulations for 1994 and Later Model Year Urban Buses, Test Procedures for Urban Buses, and Oxides of Nitrogen Emission Regulations for 1998 and Later Model Year Heavy-Duty Engines." March 24,1993. 58 FR 15781.

4. "Updated Vehicle Survivability and Travel Mileage Schedules", November 1995, U.S. Department of Transportation / National Highway Traffic Safety Administration (NHTSA). Tables 10-13. EPA Air Docket A-97-10.

5. See memorandum from David J. Korotney to EPA Air Docket A-97-10, "Nationwide and regional population fractions," document No. II-B-07.

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8. Regulatory Impact Analysis for final rule revising the NAAQS for PM and ozone. Appendix B, "Summary of control measures in the PM, regional haze, and ozone partial attainment analyses." Contact: Scott Mathias, U.S. EPA, OAR/OAQPS.